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The Comparative Study of DCT and DWT in Blind Detection Based Digital Watermarking

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***Abstract*— Digital Watermarking is one of the data hiding technique, has been popular in today for providing copyright protection. Fundamentally, to implement a digital watermarking, there are two approaches, pixel modification based and frequency domain based. In frequency domain based watermarking techniques, DCT and DWT are commonly used and popular today. The purpose of this paper is to compare and represent watermarking performance with the same technique, the two techniques; DCT and DWT are presented with new approach. At first, the new approach watermarking technique is discussed and proposed. In the technique, on-line handwritten signature is acquired from G-Pen F350 tablet, which is used as watermark. Watermark is embedded in mid-band DCT domain. On the other hand, LH band of DWT is used as embedded media.Finally with the help of experimental results, several performance analyses over the robustness of watermark against various attacks of each technique are compared to determine which technique is better.**

***Index Terms*— Digital watermarking, Discrete Cosine Transform (DCT) domain, Discrete Wavelet Transform (DWT) domain.**

I. Introduction

At present, our digital era provides many economic opportunities such as cheap distribution and also faces serious risks in distribution of illegal copies. More precisely, thousands of digital media such as audio, video, images, and other multimedia documents, are being distributed over the communication networks. Because of digital media can be copied easily, many illegal digital media products are also being distributed at the same time. Copyright and ownership mechanism can stop distributing illegal copies. In order to provide these mechanisms, the use of digital watermarking is becoming popular. Actually, digital watermarking is a technique in which secret information called watermark is embedded to a particular digital media. Here, the watermark may be a logo or an image or etc which can be proved who is right owner.

In digital image watermarking technique, there are two domains for a embedding a watermark, namely frequency domain and spatial domain [1] and [2]. In the frequency domain, a watermark is embedded to coefficients of the transformed image, while in spatial domain; it is directly embedded in host image pixels. In the past, there are many previous works in digital watermarking based on the both domains have been proposed.

In the frequency domain based approach, one of the first algorithms presented by Cox et al. (1997) used global DCT approach to embed a robust watermark in the perceptually significant portion of the Human Visual System (HVS) [3]. The next work of DCT is block based method and published in 2000 by Huang, J, Shi, YQ and Shi [4]. In this work, an image to be embedded is divided into non-overlap blocks and then they are transformed. In each block, transform coefficients which have large perceptual capacity are selected as DC components to be embedded. Another next publication is “Digital Watermarking based DCT and JPEG model” by M. A. Suhail and M. S. Obaidat in 2003 [5]. The work proposed digital watermarking algorithm based on discrete cosine transformed (DCT) coefficients and image segmentation.

In the other side, the watermarking process in the spatial domain based approach can simply be performed by modifying image pixels directly. In 1998, Kutter et al. [6] proposed embedding watermark bit into the blue channel of a color image by modifying the image pixels. Later, T. Amornraksa et al. [7] proposed three different techniques to improve the watermark retrieval performance of [6]. The next improvement of the watermark retrieval performance was proposed by Z. L. Aung et al. [8] by using non-linear filtering. The authors considered the watermark signal as a noise and attempted to reduce its effect by removing the noisiest pixel in the original pixel prediction process. Later, N.N.Hlaing et al. [9] proposed an improved version based on majority voting to fix all the weaknesses of previous works.

In this paper, the transformed based digital watermarking using DCT and DWT are analyzed and compared. This paper is structured as follows. Background theory of digital watermarking in spatial domain and frequency domain are studied in the next section. In section 3, our proposed systems of DCT and DWT are briefly described. In section 4, experimental results of DCT and DWT are presented by comparing between their performances depended on various attacks. Finally, some conclusion and further work are drawn in section 6.

II. Theoretical Issue

There are mainly two parts in every digital watermarking technique. These two parts are embedding in which watermark is inserted and watermark extraction in which watermark is recovered.

The spatial domain approached digital watermarking techniques are not too much complex. In the watermark embedding, watermark energy is directly added or subtracted

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to the corresponding host or cover image pixel. In the other word, the watermark embedding process can be seen as the addition of watermark and host image and the output is watermarked image. The embedding process can be demonstrated as follow [8].

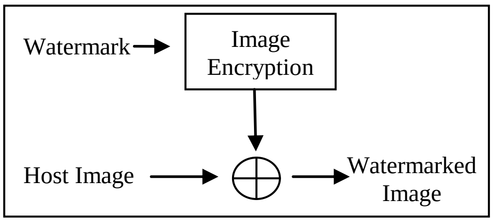


Fig.1Watermark Embedding Process in spatial domain

On another side, in the watermark recovery process, original host image can be predicted and estimated from watermarked image by removing modified watermarked pixels and replacing with the best neighbor pixels. This process is called original image prediction and the result image of the process is predicted original image, not original image. By this way, embedded watermark can be recovered by subtraction of predicted original image from watermarked image. The processes can be illustrated as followed [9].

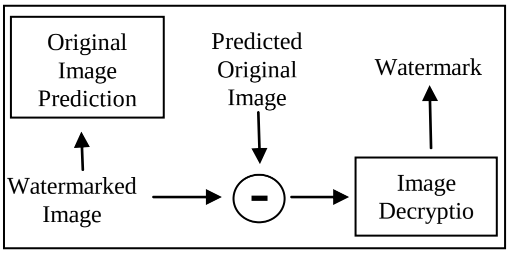


Fig. 2 Watermark Extraction Process in spatial domain

In the extraction process, several different extraction methods are used according to embedded algorithm. Commonly, averaging and correlation are used in most of the method to extract watermark bit because they are simple and efficient. The following figures describe the embedding and extraction processes in the frequency domain based watermarking.

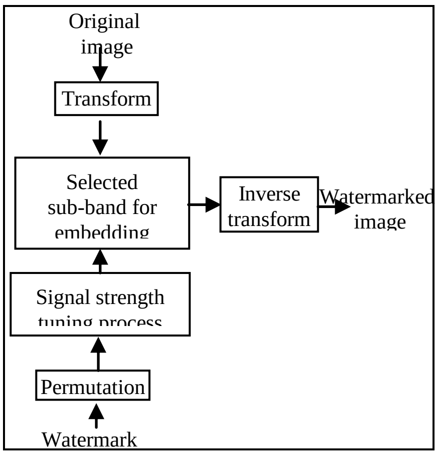


Fig.3 Watermark Embedding Process in frequency domain

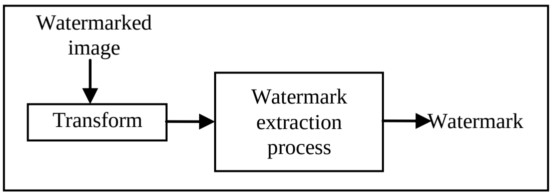


Fig.4 Watermark Extraction Process in frequency domain

The frequency domain transform based algorithms are slow compared with spatial domain based. Although frequency domain approaches methods are robust against compression and filtering attacks but weak in geometrical attacks [10]. However, they can give better perceptual transparency.

III. Proposed System

In this section, the two frequency domain based watermarking technique are presented and proposed.

A. DCT Watermarking Technique

The transform (DCT) represent an image from spatial domain to frequency domain representation as a sum of sinusoids of varying magnitudes and frequencies. It is also a reversible transformation technique. The following equations are for the two dimensional DCT transformation [11].

$$B_{pq} = \alpha_p \alpha_q \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} A_{mn} \cos\frac{\pi(2m+1)p}{2M} \cos\frac{\pi(2m+1)q}{2N} \qquad (1)$$

$$A_{mn} = \alpha_p \alpha_q \sum_{p=0}^{N-1} \sum_{q=0}^{N-1} B_{mn} \cos\frac{\pi(2m+1)p}{2M} \cos\frac{\pi(2m+1)q}{2N} \qquad (2)$$

$$\alpha(p) = \begin{cases} \frac{1}{\sqrt{N}} & , p = 0 \\ \sqrt{2/N} & ,1 \le p \le N-1 \end{cases} \qquad (3)$$

$$\alpha(q) = \begin{cases} \frac{1}{\sqrt{N}} & , q = 0 \\ \sqrt{2/N} & ,1 \le q \le N-1 \end{cases} \qquad (4)$$

Where, A is input image and B is output, transformed image. The equation 1 is transformed equation and 2 is inverse transformed. The input image is used the same number of rows and column. M is number of rows and N is number of column. The value of m, n, p and q are varies from 0 to N-1.

Watermark embedding in DCT

DCT domain watermarking can be classified into Global DCT watermarking and Block based DCT watermarking [3]. Now, the proposed technique is one of the Block based DCT. Embedding procedures are as followed.

1. Input image is divided into 8x8 sub images.

2. Each sub image is transformed with DCT.
3. Select minimum high frequency component in the transformed image and it is used as watermark energy.
4. Watermark image is permutated with a key and convert as one dimension arrays and then the array is divided into 8 elements sub arrays.
5. Watermark energy (minimum high frequency component) is inserted in the mid- band frequency of each sub image. One 8 elements watermark sub array is used for each sub image. In the mid-band frequency components of a sub image, the watermark energy is replaced whenever the watermark array element is 0. If the watermark array element is 1, there is no change in mid-band.
6. After inserting watermark energy in the mid-band of a sub image, it is inverse transformed to spatial domain.
7. All retransformed sub images are recombined to produce watermarked image.

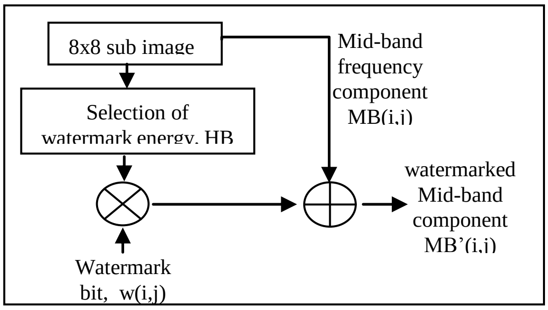


Fig.5 Watermark Embedding Process of DCT

$$MB'(i, j) = MB(i, j) + w(i, j) * HB \qquad (5)$$

Where, $MB'(i, j)$ is watermarked mid-band frequency component, $MB(i, j)$ is mid-band frequency component and *w(i,j)* is watermark bit at the location of *(i,j)*. *HB* is minimum high frequency component, used as watermark energy.

Watermark Extraction in DCT

In the extraction process, watermarked image is divided into 8x8 sub image and each sub images is transformed with DCT. In each sub image, minimum high frequency component is searched. If the high frequency component is found, 0 is placed in the respective order of recovery watermark array obeying the rule used in embedding process. If there is no found the frequency component, 1 is replaced in the recovery array. By this way, recovery watermark can be retrieved by recombining these sub arrays of each sub image.

$$\text{Recovery watermark bit is } \begin{cases} 0 \text{ if minimum high frequency is found} \\ 1 \text{ if minimum high frequency is not found} \end{cases}$$

B. *DWT Watermarking Technique*

The DWT watermarking method is not different too much with DCT watermarking as discussed. As the same as previous DCT embedding algorithm, original image is divided into 8x8 sub images. Each sub image is DWT decomposed into four frequency districts, LL, LH, HL and HH. Watermark image is also converted into one dimensional array and it is divided 8 elements sub arrays. LH band is used to embed watermark. Here, not all LH band components are used, only diagonal components of the LH band are used to embed watermark. In the LH band, minimum frequency component is selected and used as watermark energy. The watermark energy is embedded on diagonal components of the LH channel whenever watermark bit is 0. After all watermark arrays have been embedded, the sub blocks are recombined and the embedded image is returned to spatial domain by performing invert-transformation. The invert-transformed image is output watermarked image.

In the watermark extraction process, the watermarked image is firstly divided into 8x8 sub images. Each sub image is also transformed with DWT and decomposed into four frequency districts, LL, LH, HL and HH. Then, the minimum component (watermark energy) is searched in the LH band. If it is found (not found), put 0 (1) to the sub watermark array element according to the pre-define order used in embedded process. Then, after all sub watermark arrays have been recovered, they are recombined and reshaped into recovery watermark image.

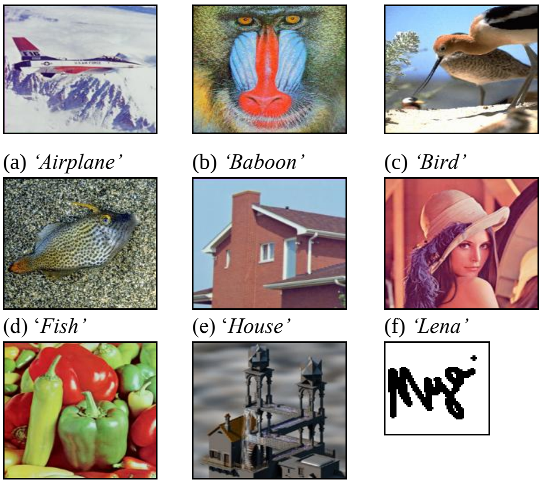
By presenting similar watermarking technique of DCT and DWT as above discussion, performances of DCT and DWT in watermarking are analyzed. The detail performance analyses can be seen in the next section.

IV. Experimental Setting & Results

In this section, the detail performance analyses and the robustness against various attacks of the two transformed techniques are presented.

A. *Experimental Setting*

In the experiments, we used eight standard color images that are different characteristics, 'Airplane', 'Baboon', 'Bird', 'Fish', 'House', 'Lena', Pepper', and 'Tower' as the original host images. A two colors black & white image containing a sign was used as a watermark signal and shown in the following Figure.



(a) *'Airplane'* (b) *'Baboon'* (c) *'Bird'* (d) *'Fish'* (e) *'House'* (f) *'Lena'* (g) *'Pepper'* (h) *'Tower'* (i) *'sign'*

Fig.6 Testing images and watermark

To measure the quality of the watermarked image the quality of the retrieved watermark, Peak Signal to Noise Ratio (PSNR) and Normal Correlation (NC) are evaluated and determined by equation (5) and (6).

$$PSNR\,(\text{dB}) = 20\log_{10}\frac{255\sqrt{3MN}}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(B'(i,j)-B(i,j))^2}} \quad (6)$$

$$NC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} w(i,j)w'(i,j)}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N} w(i,j)^2}\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N} w'(i,j)^2}} \quad (7)$$

From these equations, M and N are the numbers of row and column of the images; w(i,j) and w'(i,j) are the original watermark bit and the retrieved watermark bit at coordinate (i,j). Note that higher NC value, the retrieved watermark will be more correctly.

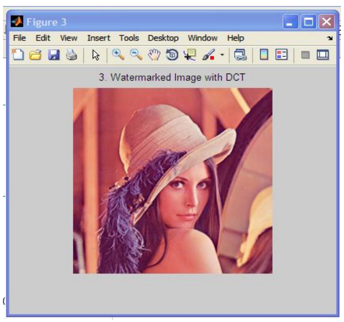
B. *Performance Comparisons*

To measure the retrieval performance of the proposed methods based on DCT and DWT, average NC values are evaluated from various images with nearly the same PSNR. The evaluation results are described as the following table.

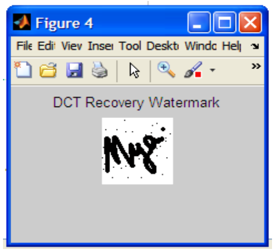
Table I. Performance comparison between DCT and DWT at different images.

Images	DCT		DWT	
	PSNR	NC	PSNR	NC
Lena	30.09381	0.995883	30.19880	0.997469
Baboon	30.32194	0.998418	30.61585	0.993681
Bird	30.19951	0.984608	30.10601	0.996229
House	30.23003	0.996041	30.54534	0.995421
Pepper	30.11686	0.996993	30.27857	0.997157
Tower	30.66638	0.976817	30.02741	0.994140
Fish	28.74961	0.947583	28.58604	0.939526
Average	30.27142	0.991460	30.29533	0.995683

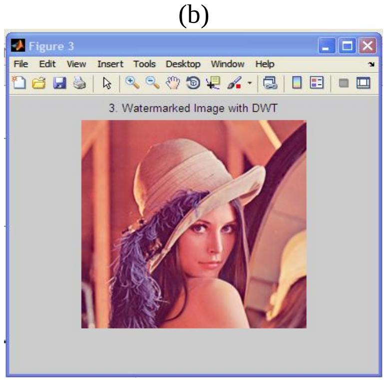
According to the table 1, the DWT transformed based technique is not better too much on DCT. The following figure shows the output result of both techniques at PSNR value of 40.



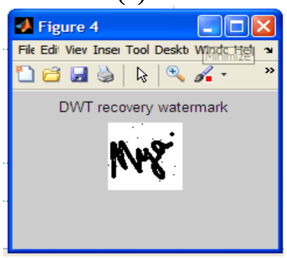
(a)



(b)



(c)



(d)

Fig.7 (a),(b)watermarked image and recovery watermark of DCT, and (c), (d) of DWT

We will continue analyze and compare the performance against image processing attacks such as JPEG compression, blurring, contrasting and sharpening, noises such as Gaussian noise and salt and pepper noise, and finally evaluate performance on geometrical attacks, image cropping and resizing. In all experiments against on the above attacks, the values of performance are estimated in *PSNR* value of 40 ± 0.01 dB. The performance comparisons are expressed as following table.

Table II. Average *NC* values obtained from various attacks at a given signal strength.

No	Type of attack	Strength	NC of DCT	NC of DWT
1	JPEG	90%	0.85635	0.6294
2	Blurring	20% of image pixel	0.93486	0.75471
3	Contrast	200%	0.93037	0.9031
4	Brightness	100%	0.96340	0.9514
5	Sharpening	90%	0.95670	0.9561
6	Gaussian noise	0.01 variance	0.86155	0.7474
7	Salt & Pepper	0.06 density	0.92603	0.9265
8	Cropping	40%	0.86719	0.7733
9	Resizing	50%	0.68540	0.5516

According to the above robustness performance comparisons, DCT of the proposed method is better than

DWT in most of the attacks. The result recovery watermark images against the above attacks are as followed.

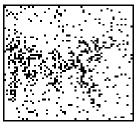
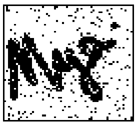
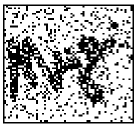
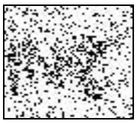
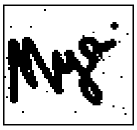
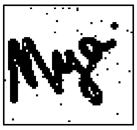
Attack	Recovery Image DCT	Recovery Image DWT
Salt&Pepper 0.03 density		
Cropping 50%		
Resizing 0.75 of original image		
JPEG 100%		
Blurring 20% of image pixel		
Brightness 30%		

Fig.8 Recovery watermark of DCT and DWT in various attacks

According to the figure 8, the proposed method is so weak in JPEG attack on both DCT and DWT. However, the proposed method can robust against most of attacks. By the proposed method, DCT watermarking is slightly better than DWT in both recovery performance and robustness against various attacks.

V. Conclusion

In this paper, we have presented block based watermarking techniques of DCT and DWT with blind detection by comparing their performances. The same technique, our proposed algorithm have been used for both DCT and DWT watermarking to measure their performances. The experimental results clearly point out which technique is better. Although frequency domain based digital watermarking techniques are usually better in perceptibility but weak in against geometrical attacks, the proposed techniques can rather against the geometrical attacks. Hence, it can be concluded that it is one of the better techniques in frequency domain based digital watermarking.

Watermark technology is so wide and rich of various techniques. As it is one of the interesting technological roads, we will continue our researches on the road, especially on neutral net based watermarking in future.

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